Science of the Total Environment 650 (2019) 2483–2489

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Investigation of environmental Kuznets curve for ecological footprint: The role of energy and financial development

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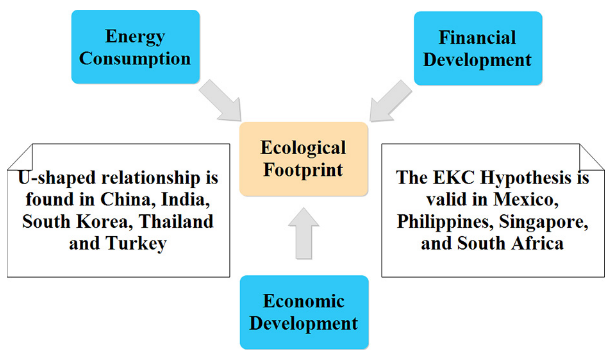
HIGHLIGHTS

- This study examines the validity of environmental Kuznets curve hypothesis.
- There is bidirectional causality between economic growth and ecological footprint.
- The study found a unidirectional causality from economic growth to energy consumption.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 11 September 2018
Received in revised form 1 October 2018
Accepted 2 October 2018
Available online 3 October 2018

Editor: Damia Barcelo

JEL classifications:
Q01
Q56
Q57

Keywords:
Economic growth
Energy consumption
Ecological footprint
Dependency
Heterogeneity

ABSTRACT

Climate change has become a global phenomenon due to its threat to sustainable development. However, economic development plays a complementary role in both climate change and sustainability. Thus, the environmental Kuznets curve hypothesis is critical to climate change policy formulation and development strategies. Accordingly, this study examined the validity of environmental Kuznets curve hypothesis by investigating the relationship between economic growth, energy consumption, financial development, and ecological footprint for the period from 1977 to 2013 in 11 newly industrialized countries. For this purpose, the study employed both augmented mean group (AMG) estimator and heterogeneous panel causality method which are suitable for dependent and heterogeneous panels. The results of the estimator show that there is an inverted U-shaped relationship between economic growth and ecological footprint. According to the causality test results, it is concluded that there is bi-directional causality between economic growth and ecological footprint.

1. Introduction

In recent decades, increasing visible signs of climate change and global warming have contributed to raising the awareness of

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https://doi.org/10.1016/j.scitotenv.2018.10.017
0048-9697/

environmental degradation (Ipcc, 2014). Similarly, the effect of economic activities on environmental degradation has become one of the most attractive topics for researchers. In this regard, the environmental Kuznets curve hypothesis is the most examined hypothesis which explains the relationship between income level and environmental pollution. According to the EKC hypothesis, environmental degradation is increased with the first stages of economic growth to a certain point, and after turning point, the economic development leads to environmental improvements, thus, an inverted U-shaped relationship between economic growth and environmental degradation (Panayotou, 1993).

Most of the studies on the relationship between economic growth and pollution have focused on utilizing carbon dioxide emissions as an indicator of environmental degradation (Salahuddin et al., 2015; Wang et al., 2016). However, carbon dioxide emissions is a portion of environmental degradation. In recent years, the ecological footprint of Wackernagel and Rees (1998) is accepted as the more comprehensive indicator to determine the degree of environmental degradation because it considers cropland, grazing land, fishing grounds, forestland, carbon footprint, and built-up land. Based on the above reasons, the main aim of this study is to examine the effect of economic growth and other possible predictors (energy consumption and financial development) on the ecological footprint for the period 1977–2013 in 11 newly industrialized countries namely South Korea, Singapore, Brazil, China, Turkey, Thailand, Malaysia, Mexico, India, South Africa and Philippines.

The developmental dynamics of the 11 newly industrialized countries make them viable candidates to be studied, to understand their role in ecological footprints and provide more insight into climate change mitigation. The contributions of this study to the existing literature are as follows; first, this is the first study to examine the relationship between economic growth and ecological footprint in newly industrialized countries. Second, as an estimation of a bivariate empirical model may lead to unreliable results, this study uses a multivariate empirical model using energy consumption and financial development as explanatory variables. Third, unlike previous studies, the methodologies used in this study consider cross-sectional dependency and country-specific heterogeneity among countries. Moreover, the empirical findings of each country can be separated using a parameter estimator and causality procedure, therefore, the obtained results will be more policy-oriented.

2. Literature review

There are several studies on the EKC hypothesis in many developed, developing and least developed economies. However, there are different outcomes leading to different policy implications. This suggests the complexity of the EKC hypothesis based on methodologies, the period of the data, and the geographical dynamics. Two categories of previous research are discussed (Table 1).

The first strand of studies examines environmental pollution, energy consumption, and macroeconomic nexus using both time series and panel data. Remuzgo and Sarabia (2015) revealed a decline of global carbon dioxide emissions by 22% due to economic development. Wang et al. (2016) revealed that shocks in carbon dioxide emissions have a small effect on GDP and energy consumption. In China, energy intensity was revealed as the main contributor to carbon dioxide emissions (Ouyang and Lin, 2015). In USA, China, Japan and India, Azam et al. (2016) confirmed a positive relationship between carbon dioxide emissions and economic growth. In Senegal, Sarkodie and Owusu (2017) revealed an increase in carbon dioxide emissions from the effect of energy consumption, financial development, and industrialization while urbanization and GDP reduce carbon dioxide emissions in the long-term. In Nigeria, it was evident that industrialization had no effect on carbon dioxide emission (Lin et al., 2015). In Sri Lanka, there was evidence of a long-run equilibrium relationship, a bidirectional causality between industrialization and energy consumption, and unidirectional causality from carbon dioxide emissions to energy consumption (Sarkodie and Owusu, 2016). In Pakistan, Mohiuddin et al. (2016a) showed evidence of long-run relationship and a unidirectional causality from energy consumption to carbon dioxide emissions. In Malaysia, there was evidence of a unidirectional causality from energy consumption to carbon dioxide emissions (Gul et al., 2015). Jammazi and Aloui (2015) confirmed a bidirectional causality between electricity consumption and economic growth and Salahuddin et al. (2015) a unidirectional causality from electricity consumption to carbon dioxide emissions.

The second strand of studies investigates the environmental Kuznets curve hypothesis. For example, Saidi and Mbarek (2016) tested the validity of EKC in 19 countries from 1990 to 2013 using the ARDL method. Their study found no proof of EKC in the 19 emerging economies. Baek (2015) found no existence of the EKC hypothesis in the 12 nuclear energy intense countries, however, nuclear energy reduces carbon dioxide emissions in the long-run. Apergis and Ozturk (2015) revealed the existence of EKC in the Asian countries while Osabuohien et al. (2014); Sarkodie (2018) validated the existence of EKC in Africa. Tiwari et al. (2013) confirmed the existence of EKC in both long run and short run equilibrium relationship in India. Shahbaz et al. (2012) confirmed the presence of EKC in a long run equilibrium relationship in Pakistan. Hamit-Haggar (2012) revealed the presence of EKC in a long run relationship and a unidirectional causality from energy consumption to greenhouse gas emissions. Pao and Tsai (2011) validated the EKC and found a bidirectional causality between foreign direct investment and carbon dioxide emissions. Nasir and Rehman (2011) revealed a positive effect of energy consumption and foreign trade on carbon dioxide emissions and confirmed the validity of the EKC. Acaravci and Ozturk (2010) revealed a long-run equilibrium relationship running from energy consumption and economic growth on carbon dioxide emissions and validated the presence of EKC in Denmark and Italy.

It is important to note that the above-mentioned literature employs a single environmental pollution indicator (carbon dioxide emissions) to examine the EKC hypothesis which is limited to consumption-based approach making it difficult to understand the dynamics of environmental pressures since available biocapacity is not considered. Significantly, the country's biocapacity affects the outcome of the EKC hypothesis. The analysis of the ecological footprint of emerging economies is critical to mitigating climate change and its impact.

3. Data and methodology

To examine the validity of environmental Kuznets curve (EKC) hypothesis, the annual data for the period 1977 to 2013 is investigated for 11 newly industrialized countries: Brazil, China, India, Malaysia, Mexico, Philippines, Singapore, South Africa, South Korea, Thailand, and Turkey. The 11 newly industrialized countries can be categorized under Very High Human Development, High Human Development and Medium Human Development based on the 2016 Human Development Index (HDI) report. Very High Human Development includes South Korea and Singapore, High Human Development includes Brazil, China, Turkey, Thailand, Malaysia and Mexico, and the Medium Human Development includes India, South Africa, and Philippines (UNDP, 2016).

According to the HDI report, Singapore, a population of 5.6 million population is ranked 5th with HDI = 0.925, exports and imports account for 326.1% of GDP, environmental sustainability stands at 9.4 t of carbon dioxide emissions per capita, a Multidimensional Poverty Index (MPI) not applicable and an Income/Composition of Resources of $78,162 Gross national income (GNI) per capita (UNDP, 2016). Singapore's energy consumption was 47,513.8 GWh of electricity in 2015, comprising of 42.3% industrial related, 36.8% commerce and services, 15% household consumption, 5.1% transport and 0.6% others. Energy imports (173.7 Mtoe) in 2015 were 65.3% petroleum products, 28.5% crude oil, 6% natural gas, 0.4% coal and peat and 0.1% others.

Table 1
Summary of literature review.

Reference	Period	Study area	Variables	Method	Interpretations
Environmental pollution-energy consumption-macroeconomic nexus					
Wang et al. (2016)	1990–2012	China	CO_2, EC and GDP	VECM	Shocks in CO_2 has a small effect on EC and GDP
Azam et al. (2016)	1971–2013	USA, China, India and Japan	CO_2, TO, EC and HC	FMOLS	Positive relationship between CO_2 and GDP in USA, China and Japan
Salahuddin et al. (2015)	1980–2012	GCC countries	CO_2, EC, FD and GDP	DOLS, FMOLS and DFE	Insignificant short-run and a positive relationship between CO_2 and EC
Sarkodie and Owusu (2017)	1980–2011	Senegal	CO_2, EC, FD, IND, URB and GDP	NIPALS	EC, FD and IND increase CO_2 while URB and GDP reduces CO_2 in the long-term.
Jammazi and Aloui (2015)	1980–2013	GCC countries	CO_2, EC and GDP	Wavelet approaches	Bidirectional causality between EC and GDP, and unidirectional causality from EC to CO_2.
Remuzgo and Sarabia (2015)	1990–2010	World data	CO_2, EI, P and GDP	Decomposition	Global CO_2 declined by 22% from 1990 to 2010
Mohiuddin et al. (2016b)	1971–2013	Pakistan	CO_2, EI, P and GDP	VECM	Evidence of long-run relationship and unidirectional causality from EC to CO_2
Ouyang and Lin (2015)	1991–2010	China	GHG, CO_2, EI, P and GDP	LMDI and cointegration	EI is main contributor of CO_2
Lin et al. (2015)	1908–2011	Nigeria	CO_2, EI, P, IND and GDP	VECM	Inverse significant relationship between IND and CO_2
Sarkodie and Owusu (2016)	1971–2012	Sri Lanka	CO_2, EC, FD, IND and GDP	ARDL and Neural Network	Evidence of long-run, Bidirectional causality between IND and EC and unidirectional causality from CO_2 to EC
Gul et al. (2015)	1975–2013	Malaysia	CO_2, and EC	MEBM	Unidirectional causality from EC to CO_2
EKC hypothesis testing					
Saidi and Mbarek (2016)	1990–2013	19 emerging economies	CO_2, INC, TO, FD and URB	ARDL	No existence of EKC
Baek (2015)	1980–2009	12 countries	CO_2, EC, NUE and GDP	DOLS and FMOLS	No existence of EKC and nuclear energy reduces CO_2
Apergis and Ozturk (2015)	1990–2011	Asian countries	CO_2, LN, P, IND and GDP	GMM	Existence of EKC
Osabuohien et al. (2014)	1995–2010	African countries	CO_2, EC, P and GDP	Panel DOLS	Existence of EKC
Tiwari et al. (2013)	1966–2011	India	CO_2, CC, TO and GDP	ARDL	Existence of EKC
Shahbaz et al. (2012)	1971–2009	Pakistan	CO_2, EC, TO and GDP	ARDL	Existence of EKC
Hamit-Haggar (2012)	1990–2007	Canada	GHG, EC and GDP	FMOLS and cointegration	Existence of EKC and a unidirectional causality from EC to GHG
Pao and Tsai (2011)	1992–2007	BRIC	CO_2, EC, FDI and GDP	VECM and Granger causality	Existence of EKC and a bidirectional causality between FDI and CO_2
Nasir and Rehman (2011)	1972–2008	Pakistan	CO_2, FT, EC and INC	VECM	Existence of EKC and a positive effect of FT and EC on CO_2
Acaravci and Ozturk (2010)	1960–2005	Europe	CO_2, EC and GDP	ARDL	Long-run relationship and existence of EKC in Denmark and Italy

Energy exports (92 Mtoe) in 2015 were 98.8% petroleum products and 1.2% crude oil (Authority EM, 2016).

South Korea is ranked 18th (HDI = 0.901), has a population of 50.3 million, exports and imports constitute 84.8% of GDP, environmental sustainability stands at 11.8 t of carbon dioxide emissions per capita, an MPI not applicable and an Income/Composition of Resources of \$34,541 GNI per capita (UNDP, 2016). South Korea ranks seventh in refined crude oil products production (141 Mt) and ranks tenth in electricity production (546 TWh) (Enerdata, 2017). South Korea's electricity generation of 546 TWh comprises of 39% coal, 31% nuclear energy, 19% natural gas, 6% crude oil, 4% other renewable energy sources and 1% hydroelectric power. South Korea produced only 1.9 million short tonnes in 2015 compared to its 146 million short tonnes consumed thus, importation of coal has increased in the last few years to meet the demand deficit. Moreover, there was the importation of crude oil (2.8 million barrels/day) and liquefied petroleum gas (1.6 trillion cubic feet) in 2015 due to the growing demand (EIA, 2017).

Malaysia is ranked 59th (HDI = 0.789), has a population of 30.3 million, exports and imports account for 134.4% of GDP, environmental sustainability stands at 8.0 t of carbon dioxide emissions per capita, MPI not applicable and an Income/Composition of Resources of \$24,620 GNI per capita (UNDP, 2016). Malaysia ranks tenth in natural gas production (67 bcm) (Enerdata, 2017). Malaysia's primary energy production comprises of 40,113 ktoe natural gas, 26,765 ktoe crude oil, 15,357 ktoe coal and coke, 6699 ktoe petroleum products, 3038 ktoe hydropower, 300 ktoe biodiesel, 181 ktoe biomass, 63 ktoe solar PV and 12 Mbiogas (MEIH, 2014).

Turkey is ranked 71st (HDI = 0.767), has a population of 78.7 million, exports and imports constitute 58.8% of GDP, environmental sustainability stands at 4.2 t of carbon dioxide emissions per capita, MPI not applicable and an Income/Composition of Resources of \$18,705 GNI per capita (UNDP, 2016). Turkey's electricity demand was 264 TWh in 2015 however, it is projected to reach 416 TWh in 2023. Currently, the primary energy demand is 125 Mtoe comprising of 35% natural gas, 28.5% coal energy, 27% oil, 7% hydropower generation and 2.5% from other renewable energy sources. The primary energy demand is projected to reach 218 Mtoe in 2023. Turkey's 99% of natural gas (48.4 bcm) and 86% of crude oil (25 million tonnes) consumed are imported (MFA, 2016).

Mexico is ranked 77th (HDI = 0.762), has a population of 127.0 million, exports and imports account for 72.8% of GDP, environmental sustainability stands at 3.9 t of carbon dioxide emissions per capita, MPI is 0.024 and an Income/Composition of Resources of \$16,383 GNI per capita (UNDP, 2016). Mexico ranks tenth in crude oil production (127 Mt) (Enerdata, 2017) and its primary energy portfolio (188 Mtoe) comprises of 51% crude oil, 32% natural gas, 7% coal, 5% bioenergy, 4% other renewable energy sources (geothermal, solar PV and wind energy) and 1% nuclear energy (IEA, 2016).

Brazil is ranked 79th (HDI = 0.754), 207.8 million population, exports, and imports constitute 27.4% of GDP, environmental sustainability stands at 2.5 t of carbon dioxide emissions per capita, MPI is 0.010 and an Income/Composition of Resources of \$14,145 GNI per capita (UNDP, 2016). Brazil ranks tenth in the global carbon dioxide emissions from fuel consumption (455 MtCO2) (Enerdata, 2017), ranks eighth in electricity production (586 TWh), eighth in refined crude oil products production (107 Mt), ninth in crude oil production (129 Mt) and third in the share of renewables in electricity production (73.5%) (Enerdata, 2017). Brazil's renewables including biofuel consumption increased by 157%, consumption of hydropower increased by 43%, gas consumption increased by 44%, oil consumption increased by 21%, nuclear energy

consumption increased by 113% and coal consumption decreased by 4% (BP, 2016).

Thailand is ranked 87th (HDI = 0.740), 68.0 million population, exports, and imports account for 131.9% of GDP, environmental sustainability stands at 4.5 t carbon dioxide emissions per capita, MPI is 0.004 and an Income/Composition of Resources of $14,519 GNI per capita (UNDP, 2016). Thailand's installed capacity as of December 2015 was 38,815 MW comprising 67% from natural gas, 5% from renewables and 28% from other sources. Consumption of imported coal amounted to 21.9 million tonnes thus, 5% increases compared to previous years due to the expansion of industrial sector consumption for production. Natural gas consumption increased by 2% thus, 4746 million cubic feet/day (EPPO, 2016).

China is ranked 90th (HDI = 0.738), 1376.0 million population, exports, and imports constitute 41.2% of GDP, environmental sustainability stands at 7.6 t carbon dioxide emissions per capita, MPI is 0.023 and an Income/Composition of Resources of $13,345 GNI per capita (UNDP, 2016). China is classified as the first of the top 5 emitters of global greenhouse gas emissions (CDIAC, 2017), ranks first in electricity production (5682 TWh), ranks first in the global carbon dioxide emissions from fuel consumption (8948 $MtCO_2$), second in refined crude oil products production (512 Mt), first in coal and lignite production (3538 Mt), ranks fourth in crude oil production (216 Mt) and has the highest energy consumption of 3101 Mtoe (Enerdata, 2017).

Philippines is ranked 116th (HDI = 0.682), 100.7 million population, exports, and imports account for 60.8% of GDP, 1.0 t carbon dioxide emissions per capita, MPI is 0.033 and an Income/Composition of Resources of $8395 GNI per capita (UNDP, 2016). Philippines economy has shifted from agrarian to industrialization with the last decade. Its primary energy demand comes from non-renewable energy sources such as oil and gas and renewable energy sources like geothermal, biomass, hydropower, wind, solar and biofuel. As at 2011, energy consumption constituted 31% oil, 22% from geothermal, 20% from coal, 12% from biomass, 6% from hydropower and 1% from wind, solar and biofuel (Energypedia, 2016).

South Africa is ranked 119th (HDI = 0.666), 207.8 million population, exports and imports constitute 62.8% of GDP, 8.9 t carbon dioxide emissions per capita, MPI is 0.041 and an Income/Composition of Resources of $12,087 GNI per capita (UNDP, 2016). South Africa has an installed capacity of 44,175 MW from which coal-fired plants constitutes 92.6%, 5.7% nuclear energy, 1.2% pumped, 0.5% hydroelectric power and 0.1% from gas turbine generation. Electricity consumption comprises of industrial activities (40.9%), residential use (36.8%), commercial use (11.4%), Transportation (2.7%) and others (8.1%). Renewable energy is projected to contribute 18.2 GW to the gross energy production (8.4 GW wind, 8.4 GW solar, 1 GW concentrated solar power and 0.4 biomass) (USEA, 2017). South Africa ranks seventh in the global coal and lignite production (248 Mt) and the highest in Africa (Enerdata, 2017).

India is ranked 131st (HDI = 0.624), 1311.1 million population, exports, and imports account for 48.8% of GDP, 1.6 t carbon dioxide emissions per capita, MPI is 0.282 and an Income/Composition of Resources of $5663 GNI per capita (UNDP, 2016). India is one of the top emitters of global greenhouse gas emissions (CDIAC, 2017), ranks third in electricity production (1368 TWh), ranks fourth in refined crude oil products production (239 Mt), third in coal and lignite production (764 Mt) and ranks third in the global carbon dioxide emissions from fuel consumption (2166 MtCO2) (Enerdata, 2017). India has an installed capacity of 329,204.53 MW from which 194,402.88 MW comes from coal, 25,329.38 MW from gas, 837.63 MW from diesel-fired plants, 6780 MW is from nuclear energy, hydropower constitutes 44,594.42 MW, and 57,260.23 MW are from newly exploited renewable energy technologies (4379.86 MW from small hydropower, 32,279.77 MW from wind energy, 8188.70 MW from biomass cogeneration, 130.08 MW from waste to energy and 12,288.83 MW from solar energy) (CEA, 2017).

Following the studies of Halicioglu (2009), Tamazian and Rao (2010), environmental pollution is described as a function of real GDP, the square of real GDP, energy consumption and financial development. The panel version of the empirical model can be written as follows;

$$\ln EF_{it} = \varphi_0 + \varphi_1 \ln Y_{it} + \varphi_2 \ln Y_{it}^2 + \varphi_3 \ln EC_{it} + \varphi_4 \ln FD_{it} + \mu_{it} \quad (1)$$

where t, i and μ_{it} refer to a period, cross-section and residual term, respectively. In addition, *lnEF* is log of ecological footprint, *lnY* (*lnY*^{2}) is log of real GDP per capita (log of the square of real GDP), *lnEC* is energy consumption per capita and *lnFD* is the credit of private sector to GDP ratio. The real GDP per capita is measured in millions of constant 2010 US dollars and energy consumption per capita is measured in kg of oil equivalent. The data of *Y*, *EC* and *FD* is obtained from World Development Indicators (World Bank, 2016), and the data of *EF* is retrieved from Global Footprint Network (Global Footprint Network, 2017).

The 1970's oil crises, the 2007 global financial crisis, and the Kyoto protocol show there is a high degree of integration on economic, financial and environmental indicators in the world. Based on this reason, this study first examines the existence of cross-sectional dependence among countries using by LM test of Breusch and Pagan (1980), CD_{LM} and CD test of Pesaran (2004) and LM_{adj} test of Pesaran et al. (2008). In addition, slope homogeneity is examined with $\Delta\sim$ and $\Delta\sim_{adj}$ test of Pesaran and Yamagata (2008).

This study uses the Augmented Mean Group (AMG) estimator developed by Eberhardt and Bond (2009), Bond and Eberhardt (2013) to consider the cross-sectional dependence and country-specific heterogeneity among countries. The other advantage of using this methodology is that it allows the examination of the parameters of non-stationary variables. Therefore, any pre-testing procedure (unit root or cointegration) is not required to use this approach. In the first step of the testing procedure, the main panel model (Eq. (1)) is estimated with the first-differenced form and *T-1* period dummy as follows;

$$\Delta EF_{it} = \gamma_1 \Delta Y_{it} + \gamma_2 \Delta Y^2{}_{it} + \gamma_3 \Delta EC_{it} + \gamma_4 \Delta FD_{it} + \textstyle\sum_{t=2}^{T} p_t(\Delta D_t) + u_{it} \quad (2)$$

where ΔD_t is first differences *T-1* period dummies; p_t is the parameters of period dummies. In the second step, estimated p_t parameters are converted to φ_t variable which indicates a common dynamic process as follows:

$$\Delta EF_{it} = \gamma_1 \Delta Y_{it} + \gamma_2 \Delta Y^2{}_{it} + \gamma_3 \Delta EC_{it} + \gamma_4 FD_{it} + d_i(\varphi_t) + u_{it} \quad (3)$$

$$\Delta EF_{it} - \varphi_t = \gamma_1 \Delta Y_{it} + \gamma_2 \Delta Y^2{}_{it} + \gamma_3 \Delta EC_{it} + \gamma_4 FD_{it} + u_{it} \quad (4)$$

The group-specific regression model is first adapted with φ_t and then the mean values of group-specific model parameters are computed. For instance, the parameter of economic growth (γ_1) can be computed as $\gamma_{1,\,AMG} = 1/N\sum_{i=1}^{N}\gamma_{1,\,i}$.

To examine the causal connections between variables, this study uses heterogeneous panel causality of Dumitrescu and Hurlin (2012). This methodology is a modified version of Granger causality and adapted to heterogeneous panel data. In addition, the Monte Carlo simulations show that this methodology gives consistent results under cross-sectional dependency. The computation of the statistic is as following;

$$W_{N,T}^{HNC} = \frac{1}{N}\sum_{i=1}^{N} W_{i,t} \quad (5)$$

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}}\left(W_{N,T}^{HNC} - K\right) \rightarrow N(0,1) \quad (6)$$

where $W_{i,\,t}$ is the Wald statistic and $W_{N,\,T}^{HNC}$ statistic is obtained with averaging each Wald statistics for cross-sections. In the testing procedure,

the null hypothesis of "there is no homogeneous causality" is tested against the alternative hypothesis that the causal relationships are heterogeneous.

4. Results and discussion

In the first step of the analysis, the cross-sectional dependence and country-specific heterogeneity were examined, and the empirical findings are shown in Table 2. According to the results, the null hypothesis that there is no cross-sectional dependence among countries is rejected for all tests. This means a shock that occurs in one of sample country may spill-over to the other countries. In addition, the homogeneity test results show that there is a country-specific heterogeneity among countries.

In the second step of our analysis, the effect of real GDP, square of real GDP, energy consumption and financial development on ecological footprint is investigated with AMG estimator. According to the results presented in Table 3, the coefficient of real GDP is positive and the coefficient of the square of real GDP is negative in Mexico, the Philippines, Singapore, and South Africa. However, the coefficient of real GDP is negative and the coefficient of the square of real GDP is positive in China, India, South Korea, Thailand, and Turkey. Therefore, an inverted U-shaped relationship is found in Mexico, Philippines, Singapore, and South Africa. Meaning that income levels increase environmental degradation at the initial stages of economic development but declines after attaining a specific turning point of income level. Sarkodie (2018) revealed that the decline in environmental pollution versus economic development can be attributed to a structural change in economic growth and technological advancement. According to Sarkodie and Strezov (2019a), as income levels increases, environmental awareness increases, thus, driving the populace to demand clean environment resulting in the enforcement of environmental laws, policies, and regulations which in turn reduces environmental pollution. On the other hand, a U-shaped relationship is supported in China, India, South Korea, Thailand, and Turkey. This results may be attributed to vintage and obsolesce energy technologies that influence economic productivity. Sarkodie and Strezov (2019b) revealed that the U-shape relationship occurs when energy intensity increases per economic outcome, thus, reducing energy efficiency. Apart from this, since China, India, South Korea, Thailand, and Turkey are industrialized countries, pollution haven hypothesis may have influenced the shape of the EKC hypothesis as revealed by Sarkodie and Strezov (2019a, 2019b). According to (Dinda, 2004); Sarkodie and Strezov (2019a), developed countries with stringent environmental policies and regulations transfer their dirty technologies to developing countries with lax environmental laws, hence, adding to their pollution stock. In addition, an increase in energy consumption leads to an increase in environmental degradation in China, India, Mexico, Singapore, and Thailand, which is in line with Sarkodie and Adams (2018). Sarkodie and Adams (2018) revealed that while clean and renewable energy technologies promote a clean environment, fossil fuel energy technologies increases environmental pollution. However, the negative coefficient of financial development on environmental degradation is found in China and Malaysia. When the group panel estimation results are evaluated, the inverted U-shaped EKC hypothesis is confirmed in newly industrialized countries.

In the third step of the analysis, the causal relationship between ecological footprint, economic growth, energy consumption, and financial development is examined with heterogeneous panel causality method. The results are illustrated in Table 4. Accordingly, there is a bidirectional causality between economic growth and ecological footprint, thus, confirming the feedback hypothesis. Economic development in industrialized economies accelerates natural resource extraction and exploitation, as such reduces the biocapacity of the environment while increasing the ecological footprint (Panayotou, 1993). However, if sustainable and management options are integrated into production and consumption, the rate of natural resource depletion and environmental stress declines, hence, allowing resources to regenerate (United Nations, 2015). Unidirectional causal relationships are found from energy consumption to ecological footprint, from ecological footprint to financial development, from economic growth to energy consumption and from economic growth to financial development. Most of the newly industrialized countries depend on the conventional form of energy sources such as coal, oil and gas. However, unlike the renewable energy technologies that are ubiquitous and sustainable, fossil fuel energy technologies are finite and unsustainable, as such, its exploitation increases the ecological footprint (Owusu and Asumadu, 2016). A unidirectional causality from economic growth to energy consumption confirms the conservation hypothesis (Inglesi-Lotz and Pouris, 2016). Meaning that economic growth drives energy consumption patterns rather than the opposite. As such, energy conservation options in the 11 newly industrialized countries will have no effect on economic development.

Table 2
Cross-sectional dependence and slope homogeneity.

	Statistic	*p*-Values
Cross-sectional dependence		
LM	161.604***	0.000
CD_{LM}	10.164***	0.000
CD	5.679***	0.000
LM_{adj}	28.913***	0.000
Homogeneity		
$\hat{\Delta}$	27.130***	0.000
$\hat{\Delta}_{adj}$	28.682***	0.000

*** Indicates significance at 1% level.

Table 3
AMG estimation results.

	lnY	lnY^2	lnEC	lnFD
Brazil	0.905	−0.031	0.357	−0.002
	[6.418]	[0.351]	[0.310]	[0.018]
China	−0.211**	0.029***	0.518***	−0.095**
	[0.104]	[0.008]	[0.059]	[0.038]
India	−0.853***	0.072***	0.662***	−0.014
	[0.323]	[0.024]	[0.134]	[0.041]
Malaysia	2.267	−0.063	−0.044	−0.145**
	[2.771]	[0.156]	[0.171]	[0.059]
Mexico	53.611*	−2.904*	0.877**	−0.046
	[29.420]	[1.642]	[0.389]	[0.051]
Philippines	28.515***	−1.907***	0.056	0.070
	[6.858]	[0.458]	[0.283]	[0.051]
Singapore	5.722**	−0.197*	0.354***	0.428**
	[2.530]	[0.106]	[0.126]	[0.173]
South Africa	42.754*	−2.381*	−0.073	0.029
	[22.845]	[1.297]	[0.102]	[0.051]
South Korea	−3.020***	0.223***	0.110	−0.036
	[0.554]	[0.036]	[0.177]	[0.048]
Thailand	−1.664*	0.141**	0.266**	0.019
	[0.935]	[0.064]	[0.114]	[0.046]
Turkey	−5.418*	0.331*	0.408	0.003
	[3.216]	[0.175]	[0.260]	[0.030]
PANEL	11.146*	−0.607*	0.828***	0.019
	[6.201]	[0.355]	[0.282]	[0.044]

Note: *, ** and *** indicates statistical significance at 10, 5 and 1% level, respectively. Numbers in brackets are standard errors.

5. Conclusions and policy implications

This study aims to examine the relationship between ecological footprint, economic growth, energy consumption and financial development in 11 newly industrialized countries. For this purpose, the annual period from 1977 to 2013 is investigated using the augmented mean group estimator and heterogeneous panel causality method. Because both methods are suitable to investigate the relationship between

Table 4
Heterogeneous panel causality test results.

	Wald Stat.	p-Value
lnY⇏ lnEF	7.725***	0.000
lnEF⇏ lnY	5.245**	0.022
lnEC ⇏ lnEF	6.218***	0.000
lnEF⇏ lnEC	4.447	0.169
lnFD⇏ lnEF	3.440	0.820
lnEF⇏ lnFD	5.229**	0.023
lnEC ⇏ lnY	3.307	0.938
lnY⇏ lnEC	4.969**	0.049
lnFD⇏ lnY	1.904	0.129
lnY⇏ lnFD	5.989***	0.001
lnFD⇏ lnEC	2.521	0.414
lnEC ⇏ lnFD	2.482	0.389

Note: *, ** and *** indicates statistical significance at 10, 5 and 1% level, respectively. Numbers in brackets are standard errors.

variables in the case of cross-sectional dependence and country-specific heterogeneity, we first test the dependence and slope homogeneity among the countries.

According to the augmented mean group estimator results, it is concluded that an inverted U-shaped environmental Kuznets curve hypothesis is supported by the panel of newly industrialized countries. It is important to note that increased levels of energy use lead to an increase in ecological footprint for these countries. When the estimator results of each country were evaluated, we found an inverted U-shaped EKC hypothesis valid in Mexico, Philippines, Singapore, and South Africa while a U-shaped relationship is found in China, India, South Korea, Thailand, and Turkey. In addition, increased energy consumption leads to an increase in environmental degradation in China, India, Mexico, Singapore, and Thailand. However, the negative coefficient of financial development on environmental degradation is found in China and Malaysia. Causality test results show that there is evidence of a bi-directional causality link between economic growth and ecological footprint. Finally, we found one-way causality running from energy consumption to ecological footprint, from ecological footprint to financial development, from economic growth to energy consumption and from economic growth to financial development.

Acknowledgements

The usual Disclaimer applies to the final version of this paper. S.A.S is funded by Macquarie University, Australia — International Macquarie University Research Training Program (iMQRTP) Scholarship.

Declaration

There is no conflict of interest.

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